

Minimal Nuclear Deterrence: a Nuclear Arsenal Reduction Plan for the United States

By

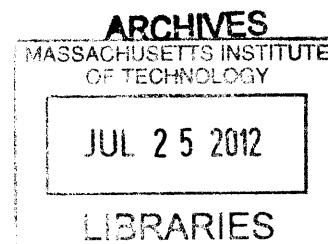
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SUBMITTED TO THE DEPARTMENTS OF NUCLEAR SCIENCE AND ENGINEERING  
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**By**

**Sarah Laderman**

**Submitted to the Departments of Nuclear Science and Engineering and Political Science**

**On May 17, 2012**

**In Partial Fulfillment of the Requirements for the Degree of  
Bachelor of Science in Nuclear Science and Engineering and Political Science**

**ABSTRACT**

The global political climate has called for reductions to nuclear arsenals around the world. This thesis researches how potential deep cuts to the United States' large strategic nuclear arsenal would affect its current nuclear deterrence goals. First, case studies on pre-1960 United States, 1964-2012 France, and 1964-2012 China are conducted to understand how a small nuclear arsenal should be constructed in order to prevent nuclear attack from countries with large nuclear arsenals. The lessons learned from these case studies, the current United States deterrence requirements, and the destructive effects from different warheads are then used to propose a potential composition of a small nuclear arsenal for the United States. The proposal consists of only around 500 warheads (in comparison to the current 2,000 the US has on deployment) and achieves United States deterrence goals through its vast destructive capability, variability, and survivability if targeted against in a first nuclear strike.

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## **List of Terms and Abbreviations**

ALCM – Air Launched Cruise Missile

ICBM – Intercontinental Ballistic Missile

kt – kilotons of TNT equivalent

LEP – Life Extension Program

MIRV – Multiple Independently targetable Reentry Vehicle

Mt – megatons of TNT equivalent

SLBM – Submarine Launched Ballistic Missile

SSBN – Nuclear-powered, ballistic missile-carrying submarine

START – Strategic Arms Reduction Treaty

WMD – Weapon of Mass Destruction

## **1. Introduction**

On the heels of the New Strategic Arms Reduction Treaty (New START) signed in 2010, it is important to look at the implications of having a reduced nuclear arsenal. More importantly, it is crucial to investigate whether or not having a small nuclear arsenal makes the United States more vulnerable to nuclear attack than it currently is. This new treaty would reduce America's nuclear arsenal only by a few hundred weapons, but would allow the arsenal to stay just upwards of 1,500 warheads. (White House Office of the Press Secretary 2010). What this paper proposes is a reduction to just over 500 weapons in the US arsenal; a third of what New START would allow the country to retain.

Why propose to reduce the stockpile of deployed weapons by that amount if both the US and Russia have agreed to let each other keep large amounts of warheads? There are two reasons: reduction trends and world safety from accidental launches/acquisition.

The first reason is treaty trends. A handful of treaties after the Cold War have proposed that both the US and Russia reduce their stockpiles from the thousands that were accumulated during the nuclear arms race era. (Graham and LaVera 2003). This trend has continued as evidenced by New START and may continue further as several world leaders have called for a race to nuclear zero (the eradication of all nuclear weapons). Without analysis of how these potential further reductions will affect United States security, leaders could blindly agree to a treaty that would leave the US open to nuclear attack. Also, if the leadership is convinced that a small arsenal would leave holes in their nation's defense, they could be hesitant to sign treaties that would potentially ease tensions. This thesis shows that a small arsenal is plausible and would keep the US safe from nuclear threats and attack.

If there is no need to further reduce arsenal sizes past what the current treaty restrictions have demanded, why should any country reduce? In order for this paper to begin its analysis, one must be convinced that disarming down to a minimum number of nuclear warheads is prudent. The first reason was reduction trends, but the second reason is for safety. As far as safety is concerned, less is more when it comes to stockpiles of nuclear weapons because of decreased chance of accidental launch or unauthorized use. Also, the larger the number of weapons one has, the greater the risk that an enemy could acquire one. If there are more weapons in the world, countries could lose one, sell off designs, or support non-state actors with their vast stores of warheads. If all countries were to agree to greatly reduce their arsenals and dismantle their

unused stockpiles, the world would be safer due to a lower risk of unintended acquisition and launch. With fewer weapons, there is less room for failure.

The two questions that this thesis attempts to answer from both political and technological perspectives are: (1) are small nuclear arsenals effective in deterring nuclear threats and attacks from nuclear enemies; and (2) if so, how can the United States use the answer from the first part to disarm safely down to an appropriately sized nuclear arsenal? The approach used to answer these questions is to examine case studies of countries with small amounts of nuclear weapons (specifically the United States in the early Cold War period, France, and China) and then apply the lessons learned from those to examine how the United States might effectively cut their arsenal number to around 500 warheads. This number was chosen because it is still accomplishes the United States' current nuclear deterrence requirements and this number is easily achievable given the composition of the US' current nuclear arsenal. Further cuts could potentially be made (as is proven through the scientific analysis of destruction effects), but deeper cuts could be less politically viable due to future domestic politics.

## **1.1 Nuclear Strategy Background**

To set the stage for this analysis, some basic terms must first be defined.

The most important policy term to understand when talking about nuclear weapons is nuclear deterrence. To deter someone means to prevent that person from doing something by showing them that the costs far outweigh the benefits of a particular action. When discussing nuclear deterrence, this means for one actor to prevent another actor from using their nuclear weapons by either frightening them with the prospect of a terrifying nuclear war or showing them that should the enemy strike first, destruction would swiftly follow. Generally, this fear or calculated inferiority is instilled using the country's own military force, whether nuclear or not. The goal is to scare the enemy into thinking that their punishment will be swift and greatly destructive should the enemy decide to attack first. Nuclear deterrence is used to prevent any first-strike that might occur against one's own country. Minimal deterrence is therefore the minimum amount of weapons needed to ensure nuclear deterrence is possible. This could be different depending on the country's goal and their specific enemy and many other factors, but there exists an arsenal that contains the absolute minimum number of warheads necessary for deterrence.

Each country's nuclear arsenal may contain three different categories of nuclear weapons. Each category makes up a leg of what is referred to as the nuclear triad. These legs are sea-based, land-based, and air-based weapons. The sea-based leg involves submarine launch ballistic missiles (SLBMs) carried on nuclear-powered submarines (SSBNs). The land-based leg involves nuclear weapons that are launched from land. This includes intercontinental ballistic missiles (ICBMs) that can travel long distances or even simple ballistic missiles that can be launched against close targets. The final leg is the air-based, which is the oldest of the three. This is any nuclear weapon that is launched from a plane. These can either be simple gravity bombs that are dropped right above the target or air-launched cruise missiles (ALCMs) that are more sophisticated and use on-board guidance systems and rockets that help them reach their target from a distance.

There is also a difference between tactical and strategic nuclear weapons. Most of the nuclear triad is made up of strategic nuclear weapons (those used to completely destroy targets that help to accomplish a long-term goal). For example, all of the cruise and long-range ballistic missiles are strategic. However, a few nuclear weapons can be considered tactical (used to win a battle, but not necessarily to accomplish long-term goals). These, however, would be used on a battlefield. They have less destructive power and are generally fired on land and not over great distances. Tactical weapons are not included in any of the total number counts or in the destruction analyses in this paper as they do not help accomplish the long-term goals of warring countries.

The specific warhead reductions called for in the New START as summarized by the Obama administration are as follows:

*"Aggregate limits:*

*1,550 warheads. Warheads on deployed ICBMs and deployed SLBMs count toward this limit and each deployed heavy bomber equipped for nuclear armaments counts as one warhead toward this limit.*

*-- This limit is 74% lower than the limit of the 1991 START Treaty and 30% lower than the deployed strategic warhead limit of the 2002 Moscow Treaty.*

*A combined limit of 800 deployed and non-deployed ICBM launchers, SLBM launchers, and heavy bombers equipped for nuclear armaments.*

*A separate limit of 700 deployed ICBMs, deployed SLBMs, and deployed heavy bombers equipped for nuclear armaments.*



*-- This limit is less than half the corresponding strategic nuclear delivery vehicle limit of the START Treaty.” (White House Office of the Press Secretary 2010).*

These are important numbers to keep in mind when looking later in this paper at the current composition of the United States strategic nuclear arsenal. As we shall see, the reduced arsenal suggested in this thesis is much less than the one outlined in the New START.

While New Start was an agreement solely between Russia and the US, they are only two members in the “nuclear club.” This informal organization includes every country that owns a legitimate nuclear weapons program (i.e. the weapon could be launched and exploded on an enemy target effectively). The founding members were the United States and the USSR (now Russia) in the 1940s and 50s.

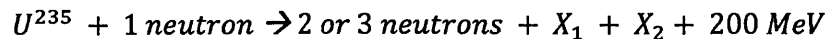
Since then, the United Kingdom, France, China, Pakistan, India, and Israel have joined (with South Africa briefly entering and quickly leaving again). North Korea possesses a few nuclear weapons, but they have no credible delivery capabilities. Iran is in the process of developing their own program, but it is not entirely known where in the process they are and how soon they could be a credible nuclear threat.

## **1.2 Nuclear Science Background**

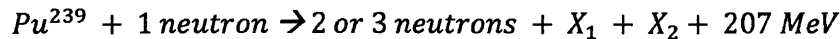
Next, it is important to understand the scientific background of nuclear weapons and their effects on targets in order to fully understand how deep reductions in arsenals affect deterrence power.

There are two different types of nuclear reactions: fission and fusion. A fission reaction is one in which a heavy atomic nucleus is caused by an impinging neutron to split into two small nuclei. This reaction continues until all the heavy nuclei have been fissioned or there are no more neutrons available to trigger another reaction. A fusion reaction is one in which two light nuclei combine to form a heavier nucleus. Both of these reactions release a certain amount of energy, which is the energy that is utilized in nuclear bombs.

A fission reaction in a bomb will look like Equation 1 or Equation 2 with the X’s on the right hand side of the equations being the lighter ‘fission product’ nuclei.



**Equation 1**

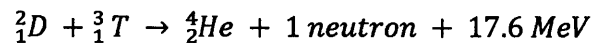


**Equation 2**

The two different materials used for fission in nuclear weapons are uranium and plutonium. The uranium found in nature consists primarily of the non-fissile U-238 isotope, with only 0.711% of the fissile isotope U-235. Thus, the natural uranium must go through an enrichment process to become mostly U-235 so that a fission chain reaction can be achieved with relatively low volumes of uranium. Pu-239 is produced in nuclear reactors via a process of neutron absorption U-238 in the fuel rods.

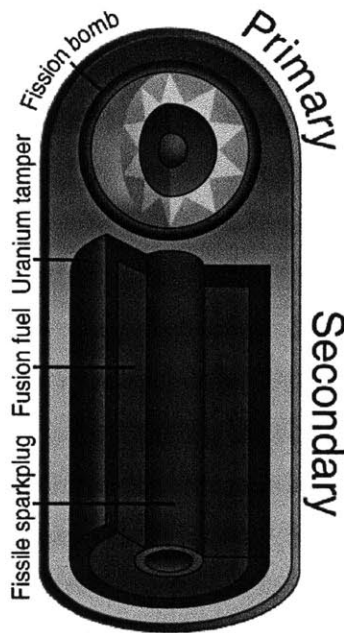
The chain reaction that is desired will continue as long as there is a critical amount of fissile material within the warhead. For each enrichment level and desired explosive yield, there is an amount of fissile material required in order for the 2-3 neutrons produced in each fission reaction to cause reactions of their own, culminating in a runaway chain reaction that releases large amounts of energy. Each of the reactions in Equation 1 and Equation 2 releases energy measured in mega-electron volt (MeV), but explosive yield (how much energy is released from an explosion) is measured in kilotons of TNT equivalent (kt). One MeV is equal to  $3.83 \times 10^{-26}$  kt, which means that in order to have a 1 kt explosion,  $2.61 \times 10^{25}$  MeV needs to be released from fission and that means around  $1.3 \times 10^{23}$  reactions need to occur.

Equation 3 shows a typical fusion reaction in a bomb. D stands for deuterium, which is a Hydrogen atom with one neutron, and T stands for tritium, which is a Hydrogen atom with two neutrons.



**Equation 3**

The fusion reaction does not produce as much energy as the fission reactions in a nuclear weapon, but it does release a neutron with every reaction. Typically, fusion is used in nuclear weapons to boost fission. The more neutrons there are feeding into the fission reaction, the more fissile material will be used and thus, a higher explosive yield will be attained. This is a basic introduction to how a Teller-Ulam device works (see Figure 1).



**Figure 1: Teller-Ulam design**  
(Wikimedia Commons 2008)

Devices with this design use the initial fission reaction in the primary to compress the secondary fuel. This initiates the fusion reaction, which causes the Uranium tamper to fission and feeds neutrons and energy back into the primary fission reaction.

There are three main effects that cause damage from nuclear weapons: overpressure waves, fires/burning, and radiation dosage. Unfortunately, there is little data as to the exact effects of nuclear weapons on humans as only two have ever been used in combat and human subjects were not used during weapons testing. There is a highly rigorous report on nuclear weapons effects, which is a little speculative because of the nature of the subject matter, but despite the inherent estimations, this source is used throughout this paper for destruction estimates. This report is Carey Sublette's "Nuclear Weapons Frequently Asked Questions" and more specifically, the chapter entitled, "5.0 Effects of Nuclear Explosions." (Sublette 1997).

The following guide for shockwave damage and injury is used throughout this paper and comes from Sublette's chapter 5:

*"1 psi: Window glass shatters. Light injuries from fragments occur.*

*3 psi: Residential structures collapse. Serious injuries are common, fatalities may occur.*

*5 psi: Most buildings collapse. Injuries are universal, fatalities are widespread.*

*10 psi: Reinforced concrete buildings are severely damaged or demolished. Most people are killed.*

*20 psi: Heavily built concrete buildings are severely damaged or demolished. Fatalities approach 100%.” (Sublette 1997).*

In order to calculate the radius of blast destruction, Equation 4 is used.

$$\text{Blast Radius} = Y^{0.33} * \text{Blast Constant}$$

**Equation 4 (Sublette 1997)**

In Equation 4 , the radius is in kilometers, Y is the yield in kt, and the blast constant varies for the different overpressure values. For 1 psi, use 2.2; for 3 psi, use 1.0; for 5 psi, use 0.71; for 10 psi, use 0.45; and for 20 psi, use 0.28. (Sublette 1997).

The next destruction calculation concerns fires. Because fire size depends greatly on environmental conditions, type of target, and other such variables, it can be difficult to predict the radius of fire damage. Lynn Eden does a masterful job of describing fire effects of nuclear weapons in her book *Whole World on Fire* (Eden 2004), however, for the purposes of this thesis, a good predictor of fire effects is of human burning. Sublette offers some excellent equations to predict the radius of damage due to the burning of human skin.

$$1^{\text{st}} \text{ Degree Burn Radius} = Y^{0.38} * 1.20$$

**Equation 5 (Sublette 1997)**

$$2^{\text{nd}} \text{ Degree Burn Radius} = Y^{0.40} * 0.87$$

**Equation 6 (Sublette 1997)**

$$3^{\text{rd}} \text{ Degree Burn Radius} = Y^{0.41} * 0.67$$

**Equation 7 (Sublette 1997)**

In these equations, Y is the yield in kt of the bomb detonated and the radius is in km.

The final, and arguably the most severe, effect is that of radiation. This is the effect that makes nuclear weapons different from other forms of WMDs or conventional bombs. Radiation can spread over great distances (depending on atmospheric conditions) and can affect people nowhere close to the target. While not always lethal, radiation does biologically affect everyone in some manner. Whether it is acute radiation sickness or simply an increased risk of cancer, radiation can affect anyone within a certain distance of the target. The way radiation dosage is measured for the purposes of this paper is using the rad unit, or, the amount of radiation that the body actually absorbs. 1 rad is equivalent to 0.01 J absorbed by 1 kg. However, the rad measure

does not take into account the biological effectiveness of the radiation as this varies by type of ionizing radiation and the part of the body that is exposed to that radiation. This relative biological effectiveness is expressed in rem. To convert rads to rems, the dose is multiplied by a quality factor, Q, that ranges from 1 to 20 depending on radiation type and biological tissue exposed. A dose of 1,000 rems is typically fatal and because this paper does not rigorously look at radiation effects of nuclear bombs, a simple measure of 1,000 rads is taken to mean fatality. Using this 1,000 rad fatality measure, Equation 8 is used to measure radiation destruction.

$$1000 \text{ rad Radiation Radius} = Y^{0.19} * 0.7$$

Equation 8 (Sublette 1997)

Again, the radius is in km and Y is the yield in kt.

## 2. Literature Review

The current hypotheses regarding nuclear deterrence strategies proposed by the literature are as follows: (1) if there are sufficient numbers of SSBNs so that one is on patrol at all times (usually at least 3 or 4 submarines are required for this to be possible if they have their maximum of 96 warheads at 350 kt each), the sea leg of the triad makes deterrence effective due to its survivability advantages; (2) land-based ICBMs make deterrence more effective only when well hidden, can be quickly launched, and have efficient command-and-control channels; (3) strategic bombers make deterrence less effective; (4) a diverse force structure makes deterrence effective; and (5) the type of nuclear weapon has no effect on deterrence, only the amount of weapons that are deployed (only a few scientists actually hold this view). Hypothesis 4 is the main point argued by this thesis, although hypotheses 1, 2, and 3 are all related and part of the argument for hypothesis 4. Hypothesis 5 is the argument that will be disproven in this thesis.

A cornerstone of this thesis is proving that the quality of a nuclear arsenal is more important than quantity when discussing national security. Quality in this case means the type of nuclear weapons and their delivery systems that the arsenal is composed of and quantity means the number of warheads that are deployed. Waltz makes an argument for this in the first chapter of his co-authored book *The Spread of Nuclear Weapons: A Debate Renewed*. Here he presents a well thought out argument that shows that any credible second-strike capability is all that is necessary as nuclear deterrence is mainly a psychological issue. If a country has a nuclear arsenal that can survive a first strike (high quality), then even a country with more weapons (high

quantity) would not risk attacking the smaller nuclear force because the larger nuclear force could still experience a damaging counter-attack. (Sagan and Waltz 2003). Richard Betts in his book *Nuclear Blackmail and Nuclear Balance* also does an excellent job of explaining some of the same concepts that Sagan and Waltz do, but he adds the term “nuclear blackmail” to the literature and uses many specific cases that show the struggle of power and the use of blackmail in negotiations regarding nuclear weapons and war. (Betts 1987). The term nuclear blackmail in Betts book means “coercion by the threat of punishment, a threat designed either to deter or to compel action by the opponent.” (Betts 1987, 4). This term is used in this thesis because it captures the psychological situation of threatening nuclear attack against a country.

An essential case study to be reviewed when writing about small nuclear arsenals is Fravel and Medeiros' paper in *International Security* called “China's Search for Assured Retaliation.” While the discussion is solely about China and the evolution of its nuclear program, there are some important conclusions and arguments that can be applied to this thesis. Most importantly, having a no-first-strike policy with a survivable, reliable, and penetrable second strike capability (only in the event of self-defense) is the key to having a small nuclear arsenal while maintaining security against large nuclear forces. (Fravel and Medeiros 2010). Putting more funds and time into strengthening one's conventional forces instead of using them to increase the number of warheads is a better use of those resources. If one has “a secure second strike capability for deterrence through assured retaliation,” (Fravel and Medeiros 2010, 87) then one can deter attacks and coercion attempts with minimal numbers of warheads. Because China is one of the cases to be analyzed in this thesis, Fravel and Medeiros piece is a good starting point to inform analysis.

From the literature review, a more well-defined answer can be given to the question posed at the beginning of this section: What does the force structure have to look like in order for a small nuclear arsenal to be considered to have a successful deterrence capability? Minimal deterrence is possible with a small, varied, survivable arsenal given that the country has a nuclear posture that is credible, consistent, and eliminates any additional vulnerability inherent in disarmament. Nuclear posture is a country's declared policy of nuclear weapon use and will be looked at further in the case studies. Disarmament can often leave a country vulnerable as enemies might see this transition period from a larger arsenal to a smaller one as a window of opportunity for attack. An important goal of disarmament is to prevent this vulnerability and

maintain the security of one's country during the transition phase and for the period of time immediately following the change to a smaller arsenal.

While there is a plethora of information available regarding minimal deterrence, the importance of nuclear posture, and quality vs. quantity arguments, there is no specific study that has flushed out what this thesis is exploring. Most of the rigorous case studies that have been conducted previously are about India [see (Kennedy 2011) as an example], Pakistan, [see (Narang 2009-10) as an example], China [see (Fravel and Medeiros 2010) as an example], as well as other countries that are still in their nuclear infancy [see (Beres and Maoz 2004) as an example] (although there have been case studies on all the nuclear countries, these were the countries most written about when research for this thesis was conducted). However, this study is different. This study uses the United States well before it achieves its peak nuclear warhead numbers, France, and China; three case studies that are very different from one another, but that have the common thread of a small nuclear arsenal. Within these cases, only situations regarding two nuclear powers going head-to-head over nuclear threats are used (except for the case where nuclear weapons were actually used by a nuclear US against a non-nuclear Japan). This thesis adds to the knowledge of minimal deterrence by looking at a new and different grouping of cases as well as delving into the technologies of arsenals and how they can help bolster a nuclear deterrence policy. This thesis also includes a proposal for how the United States can decrease its arsenal, what technologies it should keep, and what technologies can be retired from use in order to maintain current nuclear deterrence goals.

### **3. Case Studies**

#### **3.1 The United States**

The United States was in its nuclear infancy from 1945-1950 with less than 500 warheads that were solely strategic and deployed on bombers. America was the only country with tested nuclear weapons at this time, yet it still raced to build vast quantities of weapons deployed on different platforms until the peak number of strategic warheads was reached in 1975 with 2,251 ICBMs, 6,586 SLBMs, and 6,911 bombers for a total of 15,748 deployed strategic nuclear weapons. (NRDC 2002). Again, for the purposes of this paper, non-strategic weapons are

ignored so the peak weapon year is different here from what it would be if tactical nuclear weapons were included in the count.

Why did the United States proliferate so quickly and to such a high degree if it had a nuclear monopoly until 1949 when the Soviets tested their first nuclear weapon? (NRDC:2 2002) What inherent oversight in its nuclear strategy led the US to conclude that it needed to exceed the Soviet Union in total numbers of warheads and destructive power? The Soviet Union did not reach the peak of its deployed strategic nuclear weapon count until 1989 and even then, it only had 12,117 warheads (NRDC:2 2002), which was smaller than the US arsenal at the time (13,967 deployed US strategic nuclear weapons) (NRDC 2002), and even smaller than the peak US arsenal number in 1975.

In order to understand why the United States felt the need to over-populate its arsenal by such a large margin, it is important to look at the events that transpired during the beginning of the nuclear era, which shaped American nuclear strategy for decades. It is even more pertinent to look at threats that took place between the United States and other countries with nuclear weapons as this study focuses on how to deter nuclear attack from other countries. Examining cases in which the US threatens to attack countries without nuclear programs cannot fully develop the analysis needed for this thesis.

### **3.1.1 World War II and the Bombing of Japan (1945)**

The dropping of atomic bombs on Hiroshima and Nagasaki on August 6 and 9, 1945, respectively, were the only instances when nuclear weapons have been used during conflict against an enemy by any country. It is no coincidence that this occurred during a time when no other country had a tested nuclear force. No country could seek immediate retribution against the US without another use of nuclear weapons. America had complete nuclear dominance and could control nuclear events, except proliferation. Because of these two overt displays of military dominance that occurred at the close of World War II, the Soviets decided to continue with their nuclear program and try to compete with the US in nuclear superiority. Stalin even was quoted with saying to his senior officials, “Comrades – a single demand of you. Get us atomic weapons in the shortest possible time. As you know Hiroshima has shaken the whole world. The balance has been broken. Build the bomb – it will remove the great danger from us!” (Richelson 2007, 64).



While a land invasion of Asia was avoided and an end to WWII achieved, the dropping of nuclear bombs on Japan did not stop the rest of the world from developing nuclear weapons programs (although the deterrence umbrella the United States extended over Japan has prevented that country from proliferating). During the late 1940s, American intelligence discovered that the USSR was building a nuclear weapons program, but it was not until the Soviet test in 1949 that the US realized it had underestimated the Soviet's technology. (Richelson 2007). With this information, it is unsurprising that the US created so many new bombs in the early 1950s jumping from 235 strategic bombers in 1949 to 1,000 in 1953. (NRDC 2002). The United States was looking for a new balance to prevent the Soviets from gaining nuclear dominance and this was done through warhead numbers and delivery technology.

This could be said to have been an effective use of nuclear bombs since no nuclear bombs have been used in violence against a country since 1945, but I argue that this use of nuclear weapons by no means created nuclear peace; in fact, it upset the world balance by creating nuclear instability and a fight for nuclear dominance. The rest of the world did not want to meet Japan's fate, so many countries started nuclear weapons programs to ensure that they would not be attacked by a country with superior/more nuclear weapons than them and an arms race between the United States and the Soviet Union was started.

### **3.1.2 Threats in Suez (1956)**

In 1956, the strategic nuclear warhead stockpiles were as follows: United States – 3,000 (NRDC 2002), USSR – 126 (NRDC:2 2002), and the United Kingdom – 15 (NRDC:3 2002). This was also at a time before the nuclear triad had been fully established, so all strategic weapons were still delivered by bombers.

In November of 1956, during the Suez Crisis, the Soviet Union asked for British, French, and Israeli forces to remove themselves from Egypt. The USSR warned of the dangers of escalation to an atomic war should the fighting get out of hand. This was a valid threat seeing that France had not yet developed its nuclear weapons program, the UK nuclear weapons program was still in its early stages, and the USSR could have easily crushed the two countries should they have chosen to use their modest store of warheads. While this was not a direct nuclear threat against the opposing countries, it was enough of a threat for the United States to interfere and threaten the USSR on behalf of its allies. The US “also warned Moscow that nuclear attacks on Britain or France would draw U.S. retaliation.” (Betts 1987, 63). However,

this extended deterrence over a conflict that neither the US nor the USSR was directly involved in seemed to leave the United States at a bargaining disadvantage as the US allies removed their troops from Egypt without a victory. The terms were more favorable for the Soviets despite them being at a significant technological and explosive yield disadvantage to the US. The Soviet Union could have destroyed the United Kingdom and not feared a retaliatory attack because of their non-existent second strike capability, but the United States would have stepped in and destroyed the Soviet Union, as the US threatened to do. The US and its allies, however, were quick to negotiate with the Soviets and agreed to back down from their threat and remove troops from Egypt. This shows just how unstable, unpredictable, and unbelievable extended deterrence can be even when a country has vastly more nuclear weapons than the country it is trying to deter.

This case shows how the USSR was able to deter the US with a small nuclear arsenal because there was no direct threat to the United States' homeland. This case also caused France to start their own nuclear weapons program as they felt abandoned when the United States backed down from its promise and allowed British, French, and Israeli troops to be removed from Egypt with no real gain. (Betts 1987). When the US makes an extended deterrence promise, it needs to stick to its promise as the removal of the deterrence umbrella could cause that country to proliferate. This case shows that the current extended deterrence promises to South Korea and Japan need to be upheld and that the proposed small nuclear arsenal must be able to properly defend the US and these two umbrella countries.

### **3.2 France**

France performed its first nuclear test in 1960 and continued to test throughout its nuclear weapons program's early days. (Richelson 2007). However, it did not have fully operational weapons until 1964, but which time it had finally developed four bombs. Throughout its membership in the "nuclear club," France has made an estimated total of 1,260 weapons with its peak number of deployed strategic weapons at any one time in 1992 with 540 weapons. (Norris and Kristensen 2010). Of the warheads currently in its arsenal, 240 are on SSBNs, 10 on carrier-based aircraft, and the remaining 50 on land-based aircraft. (Norris and Kristensen 2008). Today, there are 300 strategic warheads still active in the French arsenal, but the French government has made it clear that they plan to cut their aircraft-based weapons numbers. There is speculation that there could be anywhere from 10-40 warheads dismantled. The number they chose was selected

upon because it meets their minimum deterrence requirements. Interestingly, the French own no tactical warheads and no ICBMs.

So why did the French decide to develop a nuclear weapons program despite having the nation with the largest nuclear force protecting them with extended deterrence? Many point to a military defeat in 1954 and the Suez Crisis in 1956:

*“In May 1954 French troops were defeated by the Viet Minh at Dien Bien Phu, signaling the end of French colonialism in Indochina and dealing a severe blow to French prestige. Development of an atomic bomb was seen as a means of restoring France’s status, and ensuring a greater voice among the Western allies. That the United States considered using atomic weapons in support of the French effort, but decided against such a dramatic action may have further spurred on the French. ... And just as, two years later, the Taiwan Straits crisis of 1958 would reinforce Mao’s desire for nuclear weapons, so the Suez Crisis of 1956 did for France. The United States pressured its allies to withdraw their forces, while the Soviet Union threatened nuclear attack if they failed to do so. The event, according to one observer, ‘demonstrated to the French military...that strategic dependence on the United States might prove worse than futile.’” (Richelson 2007, 199)*

These two instances proved to France that United States protection might not come through in a time of crisis and they wanted to protect themselves.

What is interesting about the French case though, is not why they decided to proliferate, but why they decided to keep their numbers at such a low level peaking in 1992 and then scaling back down to a low level again. The French were able to maintain relatively low levels of nuclear threats against them and thus, succeed in their nuclear deterrence despite their low warhead numbers.

This is due to the fact that France’s nuclear arsenal is extremely mobile giving it an excellent second-strike capability. Even if an enemy hit every military base and every weapons manufacturer in France, the French would still have nuclear weapons with which to destroy their enemy. There are always at least 80 SLBMs and 10 bombers at sea so there is virtually zero chance that an enemy could wipe out the entirety of France’s arsenal in one fell swoop. (Norris and Kristensen 2008). France does not have any extended deterrence promises and thus only needs weapons to protect itself and no other country.

The French case also proves that small nuclear arsenals are effective deterrents against large nuclear arsenals because the French were able to keep the Soviets at bay during the Cold

War period with their modest numbers despite the fact that the USSR could have easily crushed France, if not all of Western Europe, during that time period. The French case is an example of how an approximately 500 warhead, sea-based nuclear arsenal is viable as a nuclear deterrent against large nuclear countries.

### **3.3 China**

China's entry into the "nuclear club" occurred in 1964 when its first weapon was created and tested. Their program growth was relatively slow, but steady, focusing on the land-based leg of the nuclear triad with a few bombers utilized for variety. (Fravel and Medeiros 2010). Currently, China has around 240 nuclear warheads with only about 20-40 on bombers and the rest being land-based ballistic missiles. The Chinese have not been successful thus far in their attempt to gain operational SSBNs, but they have not given up in their attempts so this leg of the triad could become fully equipped in the next few years. (Kristensen and Norris 2011). They are also the only one of the original five proliferators to be actively increasing their arsenal. However, their policy is one of quality and not quantity so they are adding very few new warheads and only when they feel they need to diversify their force or improve their technology. (Fravel and Medeiros 2010). "China's top leaders, across several generations, embraced the notion of deterrence through assured retaliation, or the belief that a small number of survivable weapons would be enough to impose unacceptable damage in a retaliatory strike and thus deter nuclear aggression." (Fravel and Medeiros 2010, 63). In addition to the beliefs that they only need a minimum deterrent force to prevent nuclear coercion, blackmail, and attack, the Chinese have recently stated that they have specific countervalue (an enemy's cities and civilian sites) and counterforce (an enemy's military centers or personnel) targets. Should their enemies attack with nuclear weapons, all of China's targets on their enemies could still be eliminated with the nuclear force that remains. This tactic helps scare their enemies away from even threatening to use nuclear weapons as their own non-military sites could be wiped out even if the enemy only attacks military/weapons bases in their first strike against China.

So how did China come to establish a relatively modest arsenal with a no-first use policy? (Fravel and Medeiros 2010)

### **3.3.1 Soviet-Chinese Border Clashes (1969)**

In 1969, China only had 50 nuclear weapons and the USSR had 10,538 with 2,138 of those being strategic warheads. (NRDC:3 2002) (NRDC:2 2002). The Soviets vastly outweighed the Chinese both in quantity of warheads and quality of targeting and deployment, “Chinese missiles could still not even reach many important targets in Siberia.” (Betts 1987, 79). Despite the odds stacked against them, the Chinese government conducted small attacks against Soviet troops along the Sino-Soviet border. The USSR then threatened to destroy China’s nuclear weapons facilities with their own nuclear weapons. This would have almost completely wiped out China’s nuclear program, but it only takes one or two weapons to survive the attack and wipe out major cities in the USSR to perpetuate the conflict. The United States vaguely threatened to step into the conflict should it turn nuclear and punish the country that was first to use nuclear weapons. The Chinese accused the Soviet Union of nuclear blackmail, but retreated from the conflict. This US threat also stopped the USSR, after China ceased fire, from simply flattening the Chinese threat once and for all, before it grew. (Betts 1987, 79-81).

This use of blackmail and coercion against them caused the Chinese to start to develop their own nuclear doctrine, but it was not widely publicized and utilized until the end of the Cold War. They continued with their small arsenal and worked to develop their warhead delivery technologies instead of producing vast stores of warheads because they had limited access to fissile material, thus forcing their arsenal to be one of quality and not quantity at the beginning of their weapons development lifetime. The Chinese adapted to this situation and made technological changes instead of warhead additions and adopted their “no first use” policy. Their old land-based system was liquid-fueled rockets stored in caves that had to be manually set up before a second strike could be launched. That meant that most first strikes would have been effective against them, thus they had to step down and cede some of their bargaining power in 1969. Today, however, China has moved to solid-fuel rockets that are ready to launch in seconds due to improved command and control channels and well-hidden locations in vast cave networks. This means that China’s second-strike capability is more credible and thus, they have more bargaining power and resistance to nuclear blackmail.

The conclusion from this incident in 1969 is that even though the Chinese had a small arsenal, they were able to introduce hesitation into the Soviets’ minds. The USSR did not outright destroy Chinese nuclear weapons facilities; they hesitated and then the United States

stepped in which introduced even more hesitation and an eventual end to the clashes. A low-tech, 50-warhead arsenal introduced hesitation to attack in the minds of the leadership of a country with a large, high-tech nuclear arsenal. This case shows that a small nuclear arsenal is effective at preventing nuclear attack and can be made more effective given better technology and higher rates of survivability.

### **3.4 Case Study Conclusions**

There are several important points to take away from these case studies in the categories of nuclear doctrine, strategy, and arsenal composition.

(1) Extended deterrence is rarely effective even if a country has a large nuclear arsenal. This can be seen in the Suez Crisis case where the United States outnumbered the Soviets by thousands and yet the Soviets had the upper hand in negotiations and the western countries removed their troops from Egypt. A country cannot be expected to start a nuclear war over a threat or conflict that is not directly aimed at them. However, our extended deterrence policies with regards to South Korea and Japan have worked as those two countries have not yet developed nuclear weapons programs. I argue that reducing the US arsenal size would not affect our commitments in those two countries because the reduced arsenal size would still contain enough destructive power to wipe out several countries. This means that United States could eliminate a country that attacked South Korea or Japan and still have enough nuclear weapons to eliminate US enemies. The argument in this conclusion is that extended deterrence is not a viable policy for any additional countries. It has only worked with South Korea and Japan and it is doubtful another country would not proliferate simply because the US has promised nuclear retaliation on their behalf.

(2) Having a known policy of second-strike countervalue targets in addition to counterforce targets when targeting nuclear missiles will more quickly persuade an enemy not to launch a nuclear attack. A total war is a lot worse for a country than a military conflict. A country's citizens will most likely not tolerate a conflict that will result in a massive innocent death toll so leadership is less likely to allow countervalue targets to be used against them. Total war will happen when a war goes nuclear, but if a country is known to just be attacking military/nuclear bases in the middle of New Mexico, for example, there is slightly less hesitation to use force against that country than if it was known to have a target on New York City, which has a much denser civilian population. I argue that this would not cause an arms race despite the

targets on civilian populations if a no-first use policy was also adopted. These targets would only be destroyed if the opposing country struck first.

(3) Technologically advanced, survivable, second-strike capable small arsenals have been shown to be effective deterrents against nuclear attack in the above case studies, but they have not been able to prevent the proliferation of weapons into countries that previously did not have nuclear weapons programs. However, large nuclear arsenals have not been able to prevent this outcome either (as seen in conclusion 1 of this section), so there is no loss in proliferation deterrence abilities between sizes of arsenals.

(4) The actual composition of a nuclear force is much more important than the quantity of warheads a country owns. As seen in the Sino-Soviet border clashes, China had more than enough nuclear weapons to cripple the USSR economically, socially, and militarily, but their delivery methods were sub-par and they were thus able to be blackmailed by the Soviets. The Chinese then spent the subsequent period developing well hidden, easy-to-launch ICBMs with a quick response time to adequately respond to a first strike and now they have a much larger bargaining chip despite having less than 300 warheads. Their one weakness is their lack of submarines. If an absurdly large number of missiles took out the majority of China's landmass, there would be no retaliation in place because they do not have weapons at sea. Bombers would still be ineffective in this case because they would be eliminated just by virtue of being situated on land at airfields. In order to remain effective with a limited number of missiles, there must be SLBMs constantly out at sea on SSBNs with a minimum number sufficient to deter nuclear attack. That way, if a country's entire land-based arsenal was somehow eradicated, there would still be a way to perform a second strike. China has overcome this weakness by virtue of how well-hidden their nuclear bases and land-based ballistic missiles are, but submarines make any second-strike threat much more credible. France has demonstrated this due to the fact that virtually their entire arsenal is at sea.

#### **4. Future of United States Nuclear Disarmament**

All of these insights will be applied to look at the United States' current arsenal and evaluate how the government might disarm down to a minimum warhead level safely and without sacrificing any of its nuclear deterrence capabilities.

## 4.1 Current United States Strategic Arsenal

Before looking into how one might decrease the stockpile of nuclear weapons the United States deploys, it is important to look at the current composition of the arsenal and what technologies are used.

The United States' arsenal as of 2011 is composed of the following elements to complete a nuclear triad force with 1,952 strategic warheads. (Kristensen and Norris:2 2011). When a delivery system has a multiple independently targeted re-entry vehicle (MIRV), the number next to it is the number of warheads that are deployed on that system as each missile in that case would be carrying multiple warheads that could be used on different targets. The SLBMs are currently deployed on 12 SSBNs and while the US has 14 total SSBNs, two are usually in maintenance and their weapons are only counted in the stockpile and not in the actual deployed count seen below. The aircraft counted are only the number on alert and ready to attack at a moment's notice. There are many more, but they are used for training, in maintenance, or otherwise incapacitated at any given time. (Kristensen and Norris:2 2011).

### ICBMs

LGM-30G Minuteman III	450
Mk-12A (some MIRV; 1-3)	200
Mk-21	250
Warheads	
W78	250
W87	250

### SLBMs

UGM-133A Trident II D5	288
Mk-4 (MIRV; 4)	142
Mk-4A (MIRV; 4)	50
Mk-5 (MIRV; 4)	96
Warheads	
W76	568
W76-1	200



W88 \_\_\_\_\_ 384

### Bombers

Primary Mission Aircraft \_\_\_\_\_ 60

B-52H Stratofortress \_\_\_\_\_ 44

B-2A Spirit \_\_\_\_\_ 16

### Warheads

Air Launched Cruise Missile (ALCM)/W80-1 \_\_\_\_\_ 200

Gravity Bombs B61-7/-1, B83-1 \_\_\_\_\_ 100

***Total Number of Strategic Delivery Systems \_\_\_\_\_ 798***

***Total Number of Strategic Warheads \_\_\_\_\_ 1,952***

***Total Maximum Strategic Explosive Yield (Mt) \_\_\_\_\_ 570***

The total number of warheads that are stockpiled is 2,850. This means that they are operational, but not deployed. They would only be used if the entire arsenal that is deployed is used or otherwise incapacitated. The stockpile number does include tactical weapons and there is no information about the strategic vs. tactical breakdown of the stockpile weaponry. There are also thousands of warheads awaiting dismantlement due to age and/or treaty restrictions. (Kristensen and Norris:2011).

The following in-depth look into warhead and delivery system design is based in fact, but on certain issues is necessarily speculative. Information about weapon destruction capabilities, designs, and accuracies, much of which is classified, is not fully reported here. The information presented is simply that which is available from unclassified sources. To take this project into the classified realm and glean exact knowledge about the systems would be quite interesting and provide even greater insight into this topic, but unfortunately, that is not possible here.

#### **4.1.1 Land-Based Arsenal (ICBMs)**

The current delivery system for land-based warheads in the US is the LGM-30G Minuteman III. "The "L" in LGM is the Department of Defense designation for silo-launched; "G" means surface attack; and "M" stands for guided missile." (U.S. Air Force 2010). This rocket has three stages of solid propellant, which means that it can carry a heavy payload farther

than a two-stage rocket. The solid propellant means that the rocket is ready to launch at a moment's notice versus a liquid propellant rocket in which the fuel needs to be loaded before launch, thus, giving the Minuteman a reaction advantage over older liquid-fueled rockets. This ICBM can travel over 6,000 miles and reach up to 700 miles in height. The 450 Minuteman systems are located in Air Force bases in Wyoming, North Dakota, and Montana. (U.S. Air Force 2010).

The Mk-12A delivery system with a W78 warhead can either be used alone or with a MIRV and be mounted in groups of three. This delivery system is accurate within 720 feet, although this number has most likely decreased since this information was available as the W78/Mk-12A package is going through a Life Extension Program (LEP). (The Nuclear Weapon Archive 2007). The W78 warhead itself is a two-stage thermonuclear device with a supposed Teller-Ulam design and an estimated yield of 335-350 kt. (The Nuclear Weapon Archive 2006).

The Mk-21 delivery system with a W87 warhead has an accuracy of less than 400 feet and can either be used for airburst or surface explosions. It has a yield of approximately 300 kt, but can be upgraded to 475 kt with some design modifications. It is also a thermonuclear device with a Teller-Ulam design, but uses slightly different material than the W78 making it more efficient. This design is also significantly newer and has many more safety features than the previous model. (The Nuclear Weapon Archive 2006). The method to upgrade this weapon from 300 to 475 kt is by "adding rings or a sleeve of or alloy (highly enriched uranium) to the second stage. This probably entails replacing depleted uranium rings used in a cylindrical fusion tamper so that less energetic neutrons can produce additional fission." (The Nuclear Weapon Archive 2006, W87). Again, this is highly speculative and it is unknown as to how many are 300 kt or 475 kt. The official reports maintain that they are all 300 kt, but it would not be surprising if there were plans to upgrade the destructive power of these weapons, especially given the move to reduce the number of weapons in the arsenal. The US will not want to give up explosive yield just because START II demands reductions in quantity of warheads.

From the numbers above, the minimum explosive yield of the United States' land-based missiles is 158.75 Mt. The maximum explosive yield (disregarding the upgrades possible on the W87) is 162.5 Mt. For the purposes of this paper, the current total explosive yield of US ICBMs will be taken to be 160 Mt.

#### **4.1.2 Sea-Based Arsenal (SLBMs)**

The current missile system on America's SSBNs is the UGM-133A Trident II D5. Each SSBN carries 24 Trident systems so with a total of 12 submarines deployed at any given time, there are 288 Trident missiles at sea at any one moment. Each Trident can carry four warheads; therefore there are 1,152 American nuclear devices at sea at all times. This is over twice the number of land-based warheads and makes an impressive second-strike capability (or first-strike for that matter if the US was so inclined). The Trident system has a range of over 4,600 miles. (U.S. Navy 2009). While this is not as impressive as the Minuteman system, submarines can be placed anywhere in the world (well roughly 70% of the world), so this leg of the triad gives more flexibility with respect to target placement. The one disadvantage is that the SSBN will have to be already in place to launch at a specified target, but if the target changes suddenly, the SSBN will need to take time to get to that place. However, the US has addressed this weakness by keeping 12 on patrol so that they are always in the vicinity of any target that might be launched against suddenly. The Trident II rocket itself has a three-stage, solid-fuel propellant system, but its propellant is lighter than the Trident I and it can take a greater payload. The Trident II system also has an inertial guidance system for great accuracy. (U.S. Navy 2009).

The W76/Mk-4 warhead/delivery system package on the Trident II is currently undergoing refurbishment to become the W76-1/Mk-4A package. Currently 50 have been replaced, but there are still 142 Mk-4s with 568 W76s. The accuracy of the Mk-4 is not as good as the Mk-12A or Mk-21 with its error probability being at 1,250 feet. (The Nuclear Weapon Archive 2006). The W76 is a thermonuclear weapon, but only has an explosive yield of 100 kt. (The Nuclear Weapon Archive 2006). Reliable information about the accuracy and yield of the W76-1/Mk-4A was not found, but since this is an upgrade, the accuracy has almost certainly been drastically improved in addition to the safety features. The two warheads have the same explosive yield. (Kristensen and Norris:2 2011).

The W88/Mk-5 package has an accuracy of less than 400 feet and an explosive yield of 475 kt. The W88 is a fusion-boosted fission device in a conical warhead on the MIRV Mk-5 (where four W88 are packaged together). (The Nuclear Weapon Archive 2006).

One Trident missile actually has the capability of holding up to 14 warheads, but this has been limited to four due to treaty restrictions. With all of the numbers discussed above, the total explosive yield of the current United States sea-based nuclear arsenal is 259.2 Mt. For purposes

of this paper, this number will be rounded to 260 Mt. This is a full 100 Mt greater than the land-based leg of the nuclear triad.

#### **4.1.3 Air-Based Arsenal (Bombers)**

The two different types of planes in use for nuclear bombs are the B-52H Stratofortress and the B-2A Spirit. The Stratofortress can carry up to 20 ALCMs, is the only plane that can carry ALCMs in the Air Force, and has an unfueled combat range of more than 8,800 miles. (The Nuclear Weapon Archive 2007). The Spirit has extremely low visibility to the enemy, can travel at an unfueled range of approximately 6,000 miles, and can carry 16 nuclear weapons. (The Nuclear Weapon Archive 2007). The Spirit only has a crew of two whereas the Stratofortress must have a crew of five. The Spirit is also much stealthier than the Stratofortress. However, the B-52H can carry cruise missiles whereas the B-2A can only deliver gravity bombs. (The Nuclear Weapon Archive 2007). While these planes are well made and efficient at their jobs, they are still much easier to shoot down than ICBMs and easier to find than submarines as they reside in only three air bases on land in the US.

The cruise missiles used are AGM-86s (the exact model of the missile is unknown) and they have a range of a little over 1,500 miles. They fly at low altitudes and are small which makes them very capable delivery systems to get through air defenses when the B-52H cannot. (The Nuclear Weapon Archive 2007). Each one of these missiles carries only one W80-1, which is a small, lightweight, variable yield thermonuclear device. Variable yield means that this warhead can be set during flight to explode with anywhere from 5 to 150 kt of explosive yield. (The Nuclear Weapon Archive 2006). There is no accuracy rating, but these missiles use pre-loaded maps and the Earth's contours to find their pre-selected target. (The Nuclear Weapon Archive 2007).

The Spirit can only deliver gravity bombs and three main types are used. The B83-1 is the most powerful of all three and was made for high impact on concrete structures. It is a variable yield thermonuclear device that can go from only a few kilotons up to 1.2 Mt. (The Nuclear Weapon Archive 2006). The B61-7 is also a variable yield thermonuclear weapon, but its yield range is only between 10 and 340 kt. (The Nuclear Weapon Archive 2006). The B61-11 is the most interesting as it buries itself 10-20 feet underground before it explodes giving it a "bunker busting" reputation because it transfers most of its variable explosive yield (between 0.3 and 340 kt) into a more powerful ground shock. (The Nuclear Weapon Archive 2006).

With the amount of variable yield weapons in the air-based portion of the triad, it seems more prudent just to calculate the maximum possible explosive yield. Assuming each B-52H has 20 warheads deployed, there could be a possible 880 W80-1s, but the US only has a maximum of 200 deployed at a time; therefore, there is a maximum yield of 30 Mt on B52s at any given time. There are 16 nuclear, deployed Spirit airplanes and each can carry a maximum of 16 bombs. This is a total of 256 possible gravity bombs, however there are only 100 deployed at a time. The composition of this 100 is unknown but it is a mix of B61-7s, B61-11s, and B83-1s. For this maximum yield calculation, I will assume 1 B61-7, 1 B61-11, and 98 B83-1s for a maximum possible yield of 118.28 Mt. This gives an absolute maximum total air-based explosive yield of 148.28 Mt. For purposes of this paper, this yield number will be rounded to 150 Mt.

#### 4.1.4 Current Destructive Capabilities

Shown in Table 1 are the various radii of structural destruction of each explosive yield mentioned through section 4.1. Each was calculated using Equation 4 , which assumes optimal burst height and atmospheric conditions.

**Table 1: Blast pressure radii as a function of explosive yield and shock wave pressure**

<b>Blast Pressure Radii (km)</b>					
<b>Yield (kt)</b>	<b>20 psi</b>	<b>10 psi</b>	<b>5 psi</b>	<b>3 psi</b>	<b>1 psi</b>
<b>0.3</b>	0.188	0.302	0.477	0.672	1.479
<b>5</b>	0.476	0.765	1.208	1.701	3.742
<b>10</b>	0.599	0.962	1.518	2.138	4.704
<b>100</b>	1.280	2.057	3.245	4.571	10.056
<b>150</b>	1.463	2.351	3.710	5.225	11.496
<b>300</b>	1.839	2.956	4.663	6.568	14.450
<b>335</b>	1.907	3.065	4.836	6.812	14.986
<b>340</b>	1.917	3.080	4.860	6.845	15.060
<b>350</b>	1.935	3.110	4.907	6.911	15.204
<b>475</b>	2.140	3.440	5.427	7.644	16.816
<b>1200</b>	2.906	4.670	7.369	10.378	22.832

Shown in Table 2 are the radii of human damage of each explosive yield mentioned throughout section 4.1. Each was calculated using Equation 5 , Equation 6 , Equation 7 , and Equation 8, which all assume optimal burst height and atmospheric conditions.

**Table 2: Radii of various injuries to humans. 1000 rad is given here as the lethal radiation dosage.**

<b>Human Destruction Radii (km)</b>				
<b>Yield (kt)</b>	<b>Radiation death (1000 rad)</b>	<b>3rd degree burns</b>	<b>2nd degree burns</b>	<b>1st degree burns</b>
<b>0.3</b>	0.557	0.409	0.537	0.759
<b>5</b>	0.950	1.296	1.656	2.212
<b>10</b>	1.084	1.722	2.185	2.879
<b>100</b>	1.679	4.427	5.489	6.905
<b>150</b>	1.814	5.227	6.456	8.056
<b>300</b>	2.069	6.945	8.519	10.483
<b>335</b>	2.113	7.267	8.903	10.932
<b>340</b>	2.119	7.311	8.956	10.994
<b>350</b>	2.130	7.398	9.060	11.115
<b>475</b>	2.258	8.385	10.238	12.483
<b>1200</b>	2.692	12.261	14.832	17.753

Looking at the above numbers and taking the maximum destructive capabilities of each warhead, the United States can commit the destruction in Table 3. To put these large numbers in perspective, I have compared them to the surface area of the entire Earth, which is 510,072,000 square km.

**Table 3: Total destructive capabilities of the current US arsenal**

<b>United States Arsenal Maximum Destruction Radii (km)</b>			
	<b>Radii (km)</b>	<b>Area (km<sup>2</sup>)</b>	<b>Number of Earths</b>
<b>20 psi</b>	1.161E+06	4.234E+12	8.300E+03
<b>10 psi</b>	1.866E+06	1.094E+13	2.144E+04
<b>5 psi</b>	2.944E+06	2.722E+13	5.337E+04
<b>3 psi</b>	4.147E+06	5.400E+13	1.059E+05
<b>1 psi</b>	9.123E+06	2.614E+14	5.124E+05
<b>1000 rad</b>	1.234E+06	4.784E+12	9.378E+03
<b>3rd degree burn</b>	4.551E+06	6.505E+13	1.275E+05
<b>2nd degree burn</b>	5.555E+06	9.691E+13	1.900E+05
<b>1st degree burn</b>	6.772E+06	1.440E+14	2.823E+05

The current arsenal has more than enough destructive power and can be vastly reduced in size while still maintaining current nuclear deterrence goals. Again, this is the absolute highest estimate of power, whereas the real destructive power is probably much lower. It is simply impossible to know without more weapons testing and access to classified documents.

## 4.2 Applying the Case Studies

Deterrent requirements for the United States have changed since the Cold War. During the Cold War, the US had a counterforce strategy against the USSR's nuclear arsenal. It was presumed that the Soviets had a similar nuclear strategy, but there was some ambiguity as to what their true strategy was at the time. Therefore, there was an arms race to maintain a superiority over the Soviets in order to have just a few more warheads so that should counterforce targets be destroyed, there would be some nuclear weapons remaining in the US arsenal in which to annihilate the USSR. The USSR kept building up their force, so the numbers of warheads escalated quickly. There is no longer the need to build up vast stores of nuclear weapons because enemies do not have vast stores of nuclear weapons. Therefore, a smaller nuclear arsenal can be used because counterforce destruction of an enemy with thousands of nuclear weapons is no longer the goal. The current United States deterrence requirements are to protect itself from a nuclear attack on its homeland and to prevent nuclear attacks on South

Korea and Japan. This requires far fewer weapons because the arsenal is becoming a deterrent and not necessarily a total destructive force as it was in the Cold War. Also, the enemy is no longer the Soviet Union, but countries with much smaller nuclear arsenals.

The other difference between Cold War deterrence needs and current deterrence needs of the United States is that this arsenal is no longer needed to deter conventional war. In the Cold War, a land invasion of Europe by the USSR would have been extremely costly so the US used its arsenal as a threat against the Soviets should they invade conventionally. This conventional deterrence is no longer a needed goal of the United States nuclear arsenal; therefore, the arsenal can be much smaller.

Due to differences in geography relative China and France, the United States needs to have ICBMs with longer range so as to reach potential enemies. The US must also have an impressive nuclear naval presence because of their large coastal regions. America is fairly isolated from the rest of the world because of the giant oceans between them and their important enemy targets. This means, that the US case should use Chinese strategy regarding ICBMs, but also borrow from the French sea-based strategy. Both the Chinese and French have effective small nuclear arsenals, so lessons from those cases are wisely used.

(1) *Do not maintain the air-based leg of the triad.* The US is planning on spending around \$1 billion to update their nuclear aircraft for more effective delivery, but this money is better spent on other applications since in the modern world of ICBMs, bombers are rather redundant. (Kristensen and Norris:2 2011). Missile defense systems around the world have been proven ineffective while air defense systems have gained efficiency over time. An ICBM is more likely to reach its target than an airplane, so there is no need to have planes in a small arsenal when every weapon and delivery system counts.

(2) *Only have one warhead delivered with each missile ("de-MIRV" everything).* With a small arsenal, storing many warheads at the same site is not an effective means to ensure a credible second-strike capability because the enemy might think if they hit only a few targets they could take out most of the force. This also drastically reduces the number of warheads while still maintaining good delivery system variety in a minimal nuclear arsenal.

(3) *Move the ICBMs out of simply one region in the country and reduce their numbers.* Currently, the entire ICBM population is clustered in Wyoming, Montana, and North Dakota; these states are quite close to each other. If the ICBMs were spread out at different air bases,



there would be less chance of them all being destroyed in an effective first-strike maneuver against the US and it would give the appearance of adding variety in their targets (especially those of countervalue and counterforce). The reason their numbers should be reduced is that the United States is isolated by large oceans from its main targets. This makes ICBMs much less effective at nuclear deterrence than SLBMs. If a small arsenal is to be maintained, the majority of the firepower should be on submarines.

With all the above recommendations in mind, it is possible to show that the arsenal can and could be reduced to approximately 500 warheads and still maintain the destructive power necessary to satisfy current deterrence needs. This is still more than any other nuclear country (except for Russia, but they might be willing to disarm if they knew the US was going to) and enough to adequately deter nuclear attack from any country. There is enough destructive power in 500 warheads that any enemy would be severely crippled, if not completely destroyed, during a second strike. Even if a first strike eliminated half of the United States nuclear arsenal (which is highly unlikely), 250 warheads hold enough explosive yield to deter a nuclear attack from any country. This amount is enough to even take on multiple nuclear adversaries. This means that if the US should happen to have two nuclear enemies threatening first strike or need to exact retribution due to its previous extended deterrence promises, it could.

The arsenal proposed here is survivable and varied enough to be effective should most scenarios arise. Granted, if more than two or three countries were threatening nuclear attack, a small nuclear arsenal would not be enough to deter first use. However, in this scenario, I argue the United States does not need to provide the only deterrent power. It would be in the world's best interest to prevent this type of attack as the ramifications would be felt across the globe, making this a situation that does not need to be accounted for in this disarmament plan as NATO and other nuclear countries that are in an alliance with the US would likely step in to help deter a multiple nuclear adversary situation. Therefore, any situation less than a global nuclear faceoff must be deterred against. The disarmament plan outlined in the next section can accommodate any of those situations in which deterrence against nuclear attack is needed.

### **4.3 Disarmament Plan**

Following recommendation (1), removing the air-based portion of the United States arsenal will reduce the strategic numbers down to 1,652 warheads. Following recommendation (2), keeping just one warhead per missile will take the total arsenal number down to 738 nuclear

weapons. Following recommendation (3), reducing the ICBM numbers by one half will leave the US with 513 total strategic warheads.

Given just a rough cut, the new arsenal would be composed of the following:

#### ICBMs

LGM-30G Minuteman III	225
Mk-12A	100
Mk-21	125
Warheads	
W78	100
W87	125

#### SLBMs

UGM-133A Trident II D5	288
Mk-4	142
Mk-4A	50
Mk-5	96
Warheads	
W76	142
W76-1	50
W88	96

***Total Number of Strategic Delivery Systems*** 513

***Total Number of Strategic Warheads*** 513

***Total Maximum Strategic Explosive Yield (Mt)*** 137

This has reduced the total maximum explosive yield from 570 to 137 Mt. While this seems like a large reduction (~75%), with this explosive power spread across different targets around the world, this is still a destructive power. In Table 4, the new maximum destructive radii

are shown. Again, these are absolute maximum numbers and the real destruction zones will be much less.

**Table 4: Total destructive capabilities of the new US arsenal**

<b>United States Arsenal Maximum Destruction Radii (km)</b>			
	<b>Radii (km)</b>	<b>Area (km<sup>2</sup>)</b>	<b>Number of Earths</b>
<b>20 psi</b>	2.588E+05	2.104E+11	4.125E+02
<b>10 psi</b>	4.161E+05	5.435E+11	1.066E+03
<b>5 psi</b>	6.564E+05	1.353E+12	2.652E+03
<b>3 psi</b>	9.245E+05	2.684E+12	5.262E+03
<b>1 psi</b>	2.034E+06	1.299E+13	2.547E+04
<b>1000 rad</b>	2.873E+05	2.593E+11	5.083E+02
<b>3rd degree burn</b>	9.867E+05	3.057E+12	5.994E+03
<b>2nd degree burn</b>	1.209E+06	4.588E+12	8.995E+03
<b>1st degree burn</b>	1.484E+06	6.915E+12	1.356E+04

This is still a formidable arsenal that provides enough incentive for other countries not to attack the United States, South Korea, or Japan with a first strike. Even if that first strike was somewhat successful, the US has enough firepower to completely and totally destroy the aggressor in a second-strike capacity.

However, it is not enough to simply remove almost 1,500 strategic weapons from deployment. Those removed, the entire reserve stockpile, and those awaiting dismantlement need to actually be disassembled. Without all the reserves removed, the United States is simply shifting their massive amounts of weapons and they are not removing the inherent security risk in owning thousands of nuclear warheads.

Another inherent danger in only taking weapons out of deployment is that the rest of the arsenal could fall victim to age and technological inferiority. It is almost more important with a small arsenal to place emphasis on the Life Extension Programs (LEPs) and technological innovations because there are fewer warheads to simply “throw” at a problem country. Delivery needs to be effective almost 100% of the time and new methods of delivery should be constantly researched. Keeping up-to-date with nuclear technology is important because the arsenal should

constantly be more sophisticated than arsenals in other countries. This makes nuclear deterrence much more effective. A few technologies that should be developed further with this new arsenal are: increasing accuracy and distance of the ICBMs; increasing submarine life and time that can be spent on patrol without returning to port; and increasing accuracy and distance of the SLBMs. These are in addition to finding new bases at which to store the ICBMs.

## **5. Discussion**

There are two main discussion categories for this paper: political and technical.

### **5.1 Political Discussion**

The first point of discussion is: why reduce the nuclear arsenal to only 500 warheads? Why not lower? 500 was a rather arbitrary number that was arrived at using the broad cuts that came from the case study conclusions. As seen in Table 4, there is room for further cuts in terms of having enough explosive yield to accomplish deterrence goals, but the question is, are further cuts politically viable due to domestic politics? As long as politicians can get arsenal reduction bills passed, the arsenal could go much lower. The only requirements for the minimum number is that there is enough firepower to protect the United States, South Korea, and Japan from nuclear attack by their enemies and to keep the arsenal varied and survivable enough to accomplish a second strike should an enemy decide to mount a first strike.

The second important point is how does the actual process of disarmament leave the United States open to coercion or nuclear blackmail? I argue that making it well known that the new arsenal is going to be the second largest nuclear force in the world and that there will be no interruptions in nuclear submarine patrols or ICBM alert levels will leave the US open to disarm without vulnerabilities. If the bombers are the first to be removed, there is no interruption in the land and sea legs of the triad. Then, as the SSBNs come to port on their continued schedule, the SLBMs in port will be de-MIRVed. Once the sea-based leg reductions are enacted, the ICBMs can be individually de-MIRVed and taken out of service so that there is never a substantial decrease in operations. While the ICBMs are out of service so that reductions can be enacted, they will be moved and their new locations will be kept secret. If the de-MIRV happens simultaneously with relocation, time spent out of commission will be reduced. This suggested

plan is just one idea, but it does leave the US to maintain deterrence goals during the process of disarmament.

The final political point of discussion is the implications on testing. I have suggested that new technologies be investigated, but none of these new technologies involve the warhead itself. This means that the Comprehensive Test Ban Treaty will not be violated because any improvements to missiles or submarines can be tested with blanks or with conventional warheads. Testing situations are a non-issue with the new, small arsenal proposed in this thesis.

## **5.2 Scientific Discussion**

A major issue in the calculations in section 4 is the number of variables that go into exact predictions of destructive capabilities. Not all of these variables could be accounted for in this thesis as it would require years of testing, calculations, and model building to rigorously show just how much wind, air temperature, ground temperature, building distribution, materials, and other factors affect radiation dissemination, overpressure, and burn radii. Ideal conditions that maximize damage were used throughout this research, but there are rarely any ideal conditions in the real world, so the numbers above should be seen as the absolute highest estimate.

Another ideal condition that was assumed for all calculations was that each bomb burst in the air at its ideal height so that damage might be maximized. This, again, rarely happens in the real world. Timing mechanisms might not explode the warhead at the correct point in space or ground personnel could have miscalculated the ideal burst height. Also, the B61-11 buries itself underground, but that was not taken into account for the calculations because no credible prediction of destructive force could be found. This is the same issue for weapons that detonate as soon as they hit the ground. Obviously the shock waves would be very different for ground detonations rather than those that explode high in the air, but discovering the quantitative difference would have required more knowledge and testing than is currently available for this thesis.

## **6. Conclusion**

To reiterate the case study conclusions, if a country would like to have a strong, small nuclear arsenal with which to deter nuclear attacks and/or threats, one must do the following four things. (1) Do not promise additional extended nuclear deterrence. Keeping South Korea and

Japan under the US nuclear umbrella is plausible, but it would be wise to avoid further obligations. (2) Situate the arsenal so that it is clearly targeting the countervalue and counterforce areas of a potential enemy. A country will be less likely to threaten nuclear use if they know their civilians are in just as much danger as their military establishment. (3) Create a technologically advanced, survivable arsenal that is capable of reaching all possible targets given a successful first-strike maneuver perpetuated by the enemy.

Current deterrence goals of the United States are to prevent nuclear attack to the United States homeland, South Korea, and Japan. In order to accomplish these goals, the new, smaller arsenal should be composed of a heavily sea-based arsenal due to its high survivability and its capacity to reach a myriad of targets around the world. The United States is fairly isolated from some of its potential targets by large oceans so ICBMs are not as effective in this case as SLBMs. The arsenal could be cut down to 225 ICBMs and 288 SLBMs with the removal of all air-based weaponry and deterrence goals could still be accomplished. Air-based nuclear weapons leave open vulnerabilities as planes are easier to shoot down than missiles and it is much harder to sneak past air defenses than oceanic ones. If the land-based leg is well hidden and spread throughout the United States, it becomes much more effective than in its current state in only three bases in the upper Midwest of the country. Submarines should be improved to the point where they can be on patrol for greater amounts of time. This decreases the chance that they will be in port during an attack and allows them to be situated closer to their targets for greater amounts of time.

In conclusion, the United States could effectively decrease its nuclear arsenal from thousands of warheads down to just over 500 without any loss in nuclear deterrence capabilities. This could also encourage Russia to disarm down to a reasonable number as. Once the two major powers have disarmed down to low numbers, it is doubtful that other countries will be looking to proliferate to great numbers. While new countries might still enter the nuclear club, this has become inevitable ever since August 6, 1945 and disarming to a small force will not change that fact for better or worse. The United States should continue on the same trend it has slowly been following and decrease its arsenal safely down to only a few hundred warheads instead of a few thousand.

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